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An integrated semantic and cognitive model of presuppositional dependencies

1. General description

Our ability to interpret written or spoken language relies on both language-specific and more broadly cognitive capacities. In particular, since we build meaning *incrementally* as we process language word by word, it follows that memory plays an important role in comprehension.

The research program in this project aims at significantly expanding our understanding of the role of memory in interpretation. The project proceeds by combining the state-of-the art analyses of memory retrieval with the most successful and comprehensive theories of discourse semantics. The goal is to use this combination to gain insights into our understanding of cognitive processes underlying a semantico-pragmatic phenomenon, presupposition resolution.

1.1 State of the art

Understanding the role of memory in incremental interpretation requires an understanding of how memory recall works during interpretation. For this reason, a large part of the psycholinguistic literature focuses on the processing of *dependents*: elements whose interpretation and/or form depends on another linguistic item. An example of a dependent is a reflexive. For instance, in "The boys only talked about themselves", the reflexive "themselves" is dependent on the antecedent noun phrase "the boys", as we can see from the fact that the meaning of the reflexive is fully determined by this antecedent and that the antecedent also determines the form of the reflexive (the form must be "themselves", not "himself", "herself" etc.). Linguistic studies of reflexive-antecedent dependencies often abstract away from actual language use and study what *grammatical* factors affect the establishment of such a dependency. But dependency can also be studied taking actual language use into account: in that case the focus is on how the dependency is created during word-by-word comprehension. There is now solid evidence that antecedents do not stay in focal attention during reading, rather, they are stored and have to be retrieved from this passive state during the interpretation of the reflexive (cf. Dillon, 2014, and literature therein), and the same holds for other dependencies (McElree, 2001, McElree et al., 2003, a.o.). Given this, we would expect that comprehending the reflexive would be affected by properties that are known to influence recall. For instance, we would expect that it would take more time and/or it would be more error prone to comprehend a reflexive whose antecedent is less *active* in the sense that it is learned in a more distant past and/or is less relevant in the context. This turns out to be correct. The effect is observable on reading measures collected on the reflexive and words immediately following (cf. Gao et al., 2005, Dillon, 2014). For instance, Foraker (2003) shows that the underlined region is read faster by 50 and 200ms in (1a) and (1b), respectively, compared to (1c). One possible interpretation is that in (1a) and (1b), the antecedent *Megan* (boldfaced) is more active, since either it is a discourse topic (1a vs. 1c, cf. van Rij, 2012 for independent evidence that discourse topics are more active) or more recent (1b vs. 1c). For other cases of syntactic dependencies, it has been shown that decreasing the activation increases the chance of retrieval failure (McElree et al., 2003, Foraker et al., 2007, Martin and McElree, 2008, a.o.).

1a) **Megan** wondered if Isaac had found out that Rick wanted to invite Sally and **herself**
1b) Rick wondered if Isaac had found out that **Megan** wanted to invite Sally and **herself**
1c) Isaac wondered if **Megan** had found out that Rick wanted to invite Sally and **herself**

Facts such as these signal that dependencies require retrieval from memory. But they also provide arguments for particular comprehension models. In particular, when coupled with precise theories of cognition, they can reveal how linguistic information is encoded in memory and how word-by-word comprehension is executed. A popular line has been to combine a grammatical framework with a cognitive architecture. A cognitive architecture is a theory of the human mind that strives to summarize various hypotheses about cognition (e.g., memory, planning, learning) into one comprehensive model, usually computationally implemented. In psycholinguistics, successful approaches have been to use Adaptive Control of Thought-Rational (ACT-R, cf. Anderson et al., 2004 for a comprehensive article) or Soar (cf. Young and Lewis, 1999, Hale, 2014). Coupled with data from human performance in the interpretation of dependencies, computational models of cognitive architecture provided arguments for various aspects of comprehension, processing and working memory (cf. Lewis and Vasishth, 2005 for an introduction, Vogelzang et al. (to app.) for an overview).

An issue one might take with this line of research is that its focus is fairly narrow: it has targeted mainly syntactic phenomena (e.g. agreement, Lewis and Vasishth, 2005, reflexives, Dillon et al., 2013, negative polarity items, Vasishth et al., 2008) staying quite far removed from semantic content. The general focus on syntax in the literature also becomes apparent from the fact that existing theories have left unexplored how retrieval works beyond the sentence boundary. (Works that did consider retrieval of discourse elements, like the computational models of pronoun resolution in van Rij, 2012, Hendriks, 2016, focused on modelling acquisition data, rather than word-by-word processing). So, while there has been considerable progress in understanding the role of memory in the syntactic side of processing natural language sentences, little is known about how semantic information is recalled during comprehension.

The project aims to advance our understanding of the role of memory in comprehension by turning to a phenomenon that (a) involves purely the retrieval of content; and (b) is both intra- and intersentential in nature. The phenomenon in question is *presupposition*. A presuppositional dependent is a word or phrase that requires some information to have been established earlier. For instance, in the sentence "Bill smokes too", the so-called additive *too* signals that one needs to recall the information that someone other than Bill smokes. Sentences like this are infelicitous if the preceding discourse does not provide the relevant information. They are felicitous when it does, independent of how that information is conveyed syntactically, see (2).

2a) Jane smokes/is a smoker. Bill smokes too.
2b) Jane is a banker. #Bill smokes too. (# indicates that the sentence is infelicitous in this context)

Presupposition is a widespread phenomenon in language. Triggers of presuppositional dependencies do not just include so-called additives like *too* above, but also (among others) verbs, definite articles, possessive constructions, pronouns, cleft constructions and quantifiers. As a result, presuppositions are very common in natural discourses and, as such, they are among the core phenomena studied in linguistic semantics. In contrast, presupposition has received little attention in (psycho)linguistic cognitive modeling. This is a critical lacuna. As is clear from the example above, an important difference between presuppositional and other dependencies (such as the case of reflexives, above) is that presupposition does not involve the recall of any syntactic information, but rather directly involves the recall of information conveyed in a discourse. As such, understanding the role of memory processes in presuppositional dependencies is a crucial step forward towards a general model of the role of memory in the comprehension of natural language.

1.2 Program setup and aims

The program aims to pioneer the study of retrieval in the context of processing presupposed content in discourse. On the empirical side, the program consists of a series of experiments designed to gather data about the retrieval processes related to presupposition. The experiments are designed to reach a comprehensive understanding of presupposition processing, including both linguistic and more broadly cognitive factors. Correspondingly, the manipulations in these experiments are of two kinds: (I) linguistically relevant parameters, as defined in discourse representation theory (for instance, the level of embedding of a trigger or an antecedent); (II) extra-linguistic parameters (for instance, the distance between an antecedent and a trigger). On the theoretical side, the program has a similarly broad aim: to model the processing of presuppositions within an integrated model that connects (discourse) semantics with a cognitive architecture.

1.3 Methodology

On the empirical side, the program will use self-paced reading and eye-tracking experimental methods to gather data about word-by-word comprehension. These methods are known to be sensitive enough to capture the properties of memory recall (e.g., Boston et al., 2008, Demberg and Keller, 2008, Engelmann et al., 2013) and widespread in psycholinguistics. They also complement each other, as eye tracking gives us normal reading measures, and self-paced reading provides reading measures without backtracking, approximating listening.

On the theoretical side, the program will combine dynamic semantics with cognitive models of reading and memory recall and implement theoretical findings established in dynamic semantics, enriched by empirical findings collected in the project, into ACT-R.

1.4 Towards an integrated model

Standard models of content are traditionally not about what goes on in the mind, but rather about the relation between language and the information it conveys. By extension, linguistic models of presuppositional dependencies are first and foremost meant to explain what content the dependency involves and how this relates to the linguistic form of the discourse. Discourse representation theory (Kamp 1981, Kamp & Reyle 1993, Geurts & Beaver 2011) is a strand of dynamic semantics (Nouwen et al. 2016) that breaks with this anti-mentalistic stance by assuming a representational level of meaning. Abstracting away from details, the idea is that sentences can be mapped to representations of meaning. These representations are not just structural, they are directly interpretable. That is, they directly correspond to the truth-conditions of the relevant bit of discourse. In DRT, presupposed content also corresponds to meaning representations. The difference with regular content is that presuppositional content needs to be resolved by matching it to some other representation that is part of the larger overall discourse representation of meaning. An important advantage of DRT is that it allows one to model this resolution step (van der Sandt 1992, Geurts 1999, Bos 2003, Venhuizen 2018). For instance, within DRT, one can state a theory of what are admissible and non-admissible resolutions, and what preferences may occur between several admissible ones.

DRT's representations are first and foremost used to predict the actual meanings a discourse conveys. However, because meanings are given representational forms, there are opportunities within DRT to connect meaning to cognition. Representations have intrinsic features such as complexity or distance, which could affect the underlying comprehension processes. Despite the

long-standing claim to being a cognitive theory, the concepts intrinsic to DRT have not, indeed *could not* have been connected to actual behavioural data. This is why the proposed program will build a hybrid framework consisting of DRT and a cognitive architecture. We will explicate how DRT structures are to be mapped on cognitive models and how the resulting system can predict reading latencies during incremental interpretation tied to the resolution of presupposition. As the starting point, we will use the cognitive architecture ACT-R. We assume a bottom-up build-up of comprehension, e.g., semantics is built on top of syntax, which in turn is built on top of lower-level processes (word recognition, categorization etc.). Since our main focus is semantics, we are planning to take over other parts of the models from previous literature, assuming word recognition as indicated in other studies (cf. Dotlačil, to app.), and syntactic build-up using left-corner parsing (as applied in ACT-R in Lewis and Vasishth, 2005 ; see also Hale, 2014).

1.5 Programmatic setup

We operationalize the research program in three sub-projects. Two of these lean towards a more empirical focus, establishing the retrieval processes that are part of presupposition resolution by comparison to broadly cognitive factors known to influence recall in syntactic dependencies (project 1, PhD) as well as by probing the role of grammatical factors specific to presupposition (project 2, PhD). The third project (postdoc) aims to develop a hybrid framework that combines discourse semantics with cognitive architectures. The applicant synthesizes the outcomes and connects it to broader questions in both discourse semantics and psycholinguistics. The research program and its results are used to build bridges between communities of theoretical linguistics and of computational cognitive psychology, via their common interest in the broad artificial intelligence research agenda.

2. Program components

2.1 Sub-project 1 (PhD 1): General cognitive aspects of retrieval in presupposition resolution

The aim of this sub-project is to establish facts about the recall of antecedents in presupposition resolution and compare them to the state of the art knowledge on retrieval in language processing. The project focus is on two research questions, both of which are to be addressed by a series of self-paced reading and eye-tracking experiments:

RQ1. *Can we find evidence that presupposition resolution is affected by the level of activation of the antecedent?*
RQ2. *Does the search for the antecedent proceed in a parallel or serial fashion through the discourse?*

RQ1: activation of antecedents – The reading time or the proportion of failed recall of syntactic dependencies increases as the activation of antecedents decreases (cf. McElree et al., 2003, Dillon, 2014), which can be taken as evidence that items needed for the interpretation of dependents have to be retrieved from memory. We would expect that the same is true for resolving presuppositional antecedents. This issue, which has not been investigated in detail so far, will be addressed in the sub-project. At least two factors will be investigated with respect to activation: recency and context activation. With respect to recency, it will be tested whether having more distant antecedents slows down the reading of presuppositional triggers, as is the case for (some instances of) syntactic dependency (cf. Lewis and Vasishth, 2005 and literature therein). More concretely (and simplifying

slightly for illustrative purposes), we want to see if the underlined region in (3a) is read slower than in (3b) and even slower than in (3c), compared to a baseline (presupposition-less) condition. (The relevant presuppositional dependency is boldfaced.)

3a) Mary's father **is a smoker**. Mary will surely be angry when she finds out that her kids **smoke too**.
3b) Mary's father **is a smoker**. Mary is surely angry that her kids **smoke too**.
3c) Mary's father **is a smoker** and Mary's kids **smoke too**.

Context activation will be studied on cases that vary the prominence of presuppositional antecedents. For example, the facts attached to subjects should play a more prominent role than facts attached to other arguments since subjects standardly form discourse topics. It will be studied whether the prominence translates into the speed of retrieval. More concretely (and slightly simplifying), we want to see if the predication of smoking is recalled faster in (4a) than in (4b) after controlling for the role of recency.

4a) Mary's father, who **is a smoker**, met Sue and said that Mary **smoked too**.
4b) Mary's father met Sue, who **is a smoker**, and said that Mary **smoked too**.

RQ2: Parallel versus serial search – Recently, a lot of discussion has been generated by the question whether dependencies are resolved through parallel search, in which comprehension has a direct access to memory representations, or through serial search, in which resolving dependencies requires proceeding through potential antecedents case by case. The sub-project will investigate what the position of presupposition is.

If search is serial then an open question is what the order of search is. In syntax, it has been argued that at least in some cases, search might be parasitic on a hierarchical information, c-command (cf. Dillon, 2013), e.g., search proceeds one c-commanding noun phrase after another until a matching antecedent is found (but see Kush et al., 2014). Taking this as our starting point, we note that discourse interpretations also recognize hierarchical structures. In particular, it has been argued that a discourse is split into sub-discourses that are hierarchically organized and presupposition can find its antecedent only in the same sub-discourse or in the sub-discourses that are higher on the hierarchy (van der Sandt, 1992). The research question is whether these sub-discourses are searched serially, case, by case, or in parallel (see also Schwarz 2016, Schwarz and Tiemann 2017).

In general, the sub-project will establish basic facts about interpreting presuppositional dependencies using standard on-line (word by word) measures. Since the same research questions have been posed about and investigated in syntactic dependencies, the findings can be straightforwardly connected to other psycholinguistic research. However, the sub-project does not just bring more data of the same kind to the study of dependency. It arguably supplies qualitatively new data types, since unlike previous studies, the focus here is on a purely interpretational phenomenon. The findings of the second research question will also be of interest to semanticists, since they will provide a completely novel type of evidence for the existence of sub-discourses and their hierarchical organization. Such hierarchical organizations played an important part in semantic theorizing, and thus, having a novel experimental support for their existence is a welcomed addition (see synthesis component).

2.2 Sub-project 2 (PhD 2): Grammatical aspects of retrieval in presupposition resolution

The focus of this sub-project is on two research questions, both of which are to be addressed by a series of self-paced reading and eye-tracking experiments:

RQ1. To what extent is the retrieval process in presupposition resolution subject to interference by inaccessible antecedents?
RQ2. How do presupposition-specific aspects of the resolution process affect retrieval?

Both questions revolve around the issue of what information is used in recalling the antecedent of presupposition. Consider (5). In resolving the presupposition triggered by the particle *too*, readers have to recall that *lifted a box* was mentioned before. How is this achieved?

5) John **lifted a box** and Bill **lifted a box**, too.

In studies on syntactic dependencies, it has proven to be illuminating to consider interference from inaccessible antecedents. Take, for instance, a sentence like (6). If the dependency is established by simply considering [+male, +c-commanding] antecedents then it is irrelevant whether an interfering non-c-commanding noun phrase, like *Bill*, matches the reflexive in gender features or not.

6) *Bill*'s **father** talked about **himself**.

But it could also be that the search proceeds one feature after another, or that one feature, e.g., gender, plays a dominant role. In that case, the gender of the non-commanding noun phrase would interfere in search (and it could cause a slowdown or speed-up, depending on other aspects of the theory of retrieval). For reflexives, it seems that this interference is absent (Badecker and Straub, 2002) but many other cases of syntactic dependencies do show interference (cf. Wagers et al., 2009 for one such case). Finding interference is also relevant for deciding whether search is parallel or serial. While the lack of interference can be understood under both types of search, the presence of interference is straightforwardly accommodated in parallel search but requires extra assumptions for serial search.

On the linguistic side, there are quite a few aspects to presupposition resolution process that are different from syntactic dependencies. In the semantic literature on presupposition resolution, there is some discussion of preference patterns among different kinds of resolution: for instance, resolving to information that is provided in the discourse is preferred over accommodation and accommodating material globally is preferred over local accommodation (van der Sandt 1992, Geurts 1999).

RQ1: Interference by inaccessible antecedents – We go beyond preferences noted in semantic literature and study the actual time course of the resolution process, the effect of accommodation and accessibility. In order to do so, we need both manipulation of the discourse structure and the availability or unavailability of an antecedent. For example, (7a) and (7b) illustrate an interesting minimal pair. In (7b) there is a close suitable antecedent. In (7a), the nearest antecedent would require partial accommodation (partial accommodation would be achieved by assuming that Sue's moving of the box was a case of lifting it). At the same time, both (7a) and (7b) are different from (5) above in that the closest antecedent "Sue had already VERB the box" is subordinated: in other words,

while it is the nearest antecedent in a linear sense, in a discourse structural sense it is considered inaccessible.

7a) Mary **lifted the box,** even though I don't think that Sue *had moved the box*. Jane **lifted the box** too.
7b) Mary **moved the box**, even though I don't think that Sue *had already lifted the box*. Jane **lifted the box** too.

In parallel to the psycholinguistic research indicated above, the sub-project will use cases such as (7a) and (7b) (compared with a baseline in which the closest antecedent is accessible) to see whether inaccessible antecedents, italicized in (7a) and (7b), interfere in presupposition resolution. Findings such as these reveal the nature of search and hierarchical structure in presupposition resolution.

RQ2: Presupposition-specific aspects – Unlike syntactic dependencies or some discourse dependencies (pronoun resolution), presupposition resolution requires retrieval of very complex objects (predicates, propositions). Thus, we can use this fact to further probe the status of such complex objects in memory. Is it so that they are recalled piecemeal, or are they recalled as a whole? In the first case, we expect interference from other predicates that are partially overlapping in meaning. More concretely, we would expect interference not only if the object in the last clause is "something" but also if it is "wine", and similarly for the verb in (8b).

8a) Mary **brought a bottle of wine**, even though Sue had already brought beer. Jane **brought something/wine** too.

8b) Mary **lifted the box,** even though Sue had already pushed the box. Jane **moved/lifted the box** too.

By considering RQ1 and RQ2, the sub-project collects data that will lead to refinement of discourse theories on the preference of resolution (Geurts 1999) and of understanding how complex semantic objects are encoded in memory and retrieved from it.

2.3 Sub-project 3 (Postdoc): computational modeling of presupposition and discourse interpretation

The sub-projects 1&2 collect data on presupposition resolution. Such data can be used to provide evidence for general aspects of retrieval mechanisms (e.g., serial vs. parallel search) as well as discourse semantics (e.g., are discourse-inaccessible antecedents retrieved?). But on-line measures (reaction times) are rich enough to allow the development of more precise theories. In particular, memory recall has been combined with other theories of cognition to deliver computational models that make predictions for word-by-word reading measures (for eye-tracking) and word-by-word key presses (for self-paced reading). A popular way has been to use cognitive architectures, such as ACT-R and Soar, and implement in them (i) parsers, along with (ii) computational theories of eye movement, such as E-Z Reader (Reichle et al., 2006), and general assumptions about memory retrieval (e.g., antecedents are recalled when dependents are interpreted). The advantage of building computational implementations lies in the fact that the resulting models explicate underlying assumptions, can be matched against quantitative data and generate precise predictions that can distinguish between approaches that seem otherwise indistinguishable (cf. Nicenboim and Vasishth, 2018 on the minute comparison of two similar parallel-search theories).

The computational implementations were used mainly to model syntactic parsing with only a few exceptions (van Rij 2012, Brasoveanu and Dotlačil, 2015). The goal of the sub-project is to provide a computational model of interpretation and presupposition resolution by implementing Discourse-Representation Theory in ACT-R. The choice of ACT-R is natural since it is familiar to the post-doc. Apart from this practical point, there are at least three theoretical reasons: (i) as noted above, it allows us to use and re-use one system for various sub-components of cognition; thus, our model can not only simulate memory retrieval, but also various other aspects, e.g., eye movements and motor actions, making the resulting model maximally realistic; (ii) it has been previously used to model dependencies and therefore, this work can be directly compared to and contrasted with previous studies; (iii) it has been extensively used to model memory recall independent of language (Anderson et al., 1998, 2004, Anderson, 2007), providing ample evidence that the architecture is applicable to simulate memory structures.

The computational implementation will proceed in two ways. First, the sub-project will hand-craft the rules that translate syntactic structures into discourse representations. Translation rules were provided in the original work on DRT (Kamp & Reyle, 1993), however, such rules are not cognitively plausible as they operate only with completed syntactic trees, whilst semantic representations do not wait, they go hand in hand with syntactic parsing (cf. Steedman, 2000). Fortunately, this fact is still compatible with syntax-to-semantics DRT translations in DRT (cf. Brasoveanu and Dotlačil, 2015). The second line is to provide a data-driven approach to the ACT-R implementation of DRT. This will be done by developing chunking (shallow parsing), which proceeds by splitting clauses into basic phrases (noun phrases, verb phrases, etc.), but does not provide a complete, hierarchical and recursive parse. However, this can already be used to build simple semantic representations (for example, chunkers are used for event recognition). That ACT-R is in principle compatible with data-driven chunkers has been shown in the proof of concept, in which we developed a data-driven chunker using the Penn Treebank (Marcus et al., 1993). The chunker had an accuracy of 89% on correctly categorizing individual words, and precision and recall for phrases 80% and 87%, respectively.

The models built in the sub-project will be tested against data collected in the sub-project 1&2. There are two potential problems here. First, having data from the other sub-projects as a prerequisite for modeling would make the success of this sub-project completely dependent on the other parts of the project. Second, using only experimental data unnecessarily limits the validity of the resulting models. After all, it is possible that people behave differently when they read on their own than when they are participants in the experiments that target their resolution of presuppositions. For this reason, the models will use another testbed, eye-tracking corpora. Two corpora will be used, the Dundee corpus (Kennedy and Pynte, 2005), which is currently the standard corpus to test and compare computational psycholinguistic theories of reading, and the GECO corpus (Cop et al., 2016), which consists of eye-tracking data for a full book, and consequently, it is ideal to study discourse relations. The second corpus will also be hand-annotated for presupposition resolution. We need to develop a sufficiently fine-grained standard for annotation that is at the same time manageable given (i) the considerable size of the annotation task and (ii) the desired connection to a framework like DRT. The hand-annotation of the corpus will be done by research assistants and managed by the post-doc.

2.4 Synthesis (PI)

The first aim of the synthesis component is to prepare a synthesizing journal article that provides a comprehensive overview of the program's results and a general assessment of its approach. The article is intended to appeal to both semantics-minded and processing-minded linguists and psychologists. It should (a) clarify the general advances with regards to our understanding of the processing of dependents; (b) advertise the approach, in particular the combination of experimental research, linguistic modeling and computational cognitive modeling; (c) connect to immediately relevant issues in semantics and psycholinguistics. Regarding (c), the article should in particular address the future use of the research results. Because the program made the role of linguistic parameters in language processing explicit, it established a baseline profile for presupposition processing data. This profile can be used by future experimental approaches that aim to differentiate between linguistic theories.

Beyond this pure synthesis, there are two additional aims:

- *Semantics*: Aspects of incremental interpretation play a role in foundational debates on semantics, i.e. debates that concern not the actual processing behavior in language use, but the mapping of form to meaning in language. Presuppositions have long-since been seen as a dynamic phenomenon (Heim 1983). More recent theoretical developments have argued, however, that they display incremental properties (Schlenker 2009, see Chemla & Schlenker 2012 for an experimental approach). That is, the idea is that linguistic properties of presupposition are in part determined by left-to-right processing. The current program will indirectly contribute to this debate by producing data on the interplay between linguistic factors and processing. In this synthesizing component, the PI will spell out this contribution and prepare a journal article that explores connections between the theoretical lines of research in semantics and pragmatics, and the program's research results.

- *Beyond presupposition*: The applicant will prepare a preliminary report that explores how the general methodological route taken in the program can be extended beyond the phenomenon of presupposition. In particular, it will compare presupposition with other so-called projection phenomena, including those where antecedents are generally absent, such as apposition (see Schlenker forthcoming for an overview, see Venhuizen et al. 2018 for a general DRT approach to all such phenomena). The report is to be used as a recommendation for avenues of further research.

2.5 Knowledge Utilization

The research conducted in this program is foundational in nature and not directly relevant to applications recognizable by the general public. I do believe, however, that there is an important indirect public relevance. There currently is a high societal and economical demand for automated services that involve natural language. In general, both commercial and non-commercial industries are hungry for a continued development of artificial intelligence (AI). This has mostly been brought about by the exponential growth of successful results in so-called narrow artificial intelligence, the discipline that develops piecemeal solutions to AI tasks, one task at a time, usually using machine learning techniques that rely heavily on the availability of extensive amounts of data. At the same time, it is evident that this approach has its limits. Narrow AI is dependent on well-defined tasks and on large domain-specific data sets. To take the step towards next generation AI, we need to build

more comprehensive theories, spanning broader sets of problems and involving closer attention to human cognition. Successfully simulating general human cognitive abilities is a prerequisite for the further advancement of artificial intelligence. The current program has the potential to allow theoretical linguistics to contribute to this broad research program. In the knowledge utilization component of the program, we therefore aim to further emphasize connections between theoretical linguistics and computational cognitive science. We do this in four ways:

1. Tutorials: Computational cognitive modeling is not so common in linguistics, but it is well-established in studies like mathematical psychology and artificial intelligence. We will use the program to bring this methodology to the attention of the linguistic community, by providing two graduate-level tutorials in national summerschool-type events (the Utrecht-based EMLAR and the schools organized by the Netherlands Graduate School of Linguistics, LOT).

2. Availability of computational modeling: the cognitive architecture that we will use (ACT-R) is currently implemented in various programming languages. We will use the Python implementation called pyactr, which has been developed by the post-doc (see the package and documentation at https://www.github.com/jakdot/pyactr). The advantage of using a Python implementation over some other versions is that Python is becoming the programming lingua franca in the academic environment. It is spreading to humanities, as well. For instance, it has been taught to Dutch PhD linguistic students at national Dutch linguistic schools (LOT). The pyactr package is usable, but during the project it will be expanded to become more user-friendly: a frontend will be added and the package will be directly usable in browsers, and we will create an interactive manual to ease learning of cognitive modeling. Having such an easily accessible working framework will further increase the awareness about cognitive modeling outside of the community of computational psychologists.

3. Outreach activities: We are planning to disseminate our results in the communities where computational models are used, bridging the gap between these fields and linguistics, thus fostering future collaborations. We'll present at relevant conferences (International Conference on Cognitive Modeling (ICCM), Cognitive Modeling and Computational Linguistics (CMCL), CogSci) and events organized by Dutch AI departments. Additionally, we plan to organize a national workshop that will intertwine linguistic and computational / AI work. The goal of this workshop is to bring together researchers with a shared broader interest (computational cognitive science) that are nevertheless part of distinct communities, thus fostering future collaborations.

4. Freely available research results: All research results will be made available for future use. In particular, the annotated GECO corpus will be freely available. We expect it to be used as a gold standard for computational cognitive models of discourse structures in the future.

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